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NOTICES

R. G. VERYARD, B.Sc.

Mr. R. G. Veryard retired from his post as Deputy Director (Central Services) of the Meteorological Office in October 1959, and some details of his official career were given in the *Meteorological Magazine* for December of that year. Mr. Veryard subsequently accepted a temporary appointment as Senior Scientific Officer and served in the Climatological Research Branch until his final retirement in October 1961. His period of service with the Meteorological Office extended over more than 42 years, though from 1925 to 1936 he was seconded for duty with the Royal Air Force in India.

Mr. Veryard's service has been mainly on the operational side of the Office. He was one of the first to be appointed Senior Meteorological Officer at a Group Headquarters in the years of rapid Royal Air Force expansion just before the Second World War. His practical common sense and clear thinking will be remembered by many colleagues who took part in the daily telephone operational conference between the Central Forecasting Office and Group Headquarters during the early war years. For a time during the difficult period of pre-war expansion Mr. Veryard was an officer of the Meteorological Office Branch of the Institute of Professional Civil Servants.

Following his return from the Middle East in 1949, Mr. Veryard was employed on special work, mainly concerned with international matters, for the Director; during this period he compiled the first edition of "Meteorological Office Standing Orders". In 1953 he was appointed Assistant Director (Climatology) at Harrow, being in charge until 1957 of the branches now comprising the Assistant Directorates of Climatological Services and Research, the Meteorological Office Library and the Cartographical Pool. During this period Mr. Veryard was chairman of the very active and successful dramatic club of the Harrow office. He was promoted to the post of Deputy Director (Central Services) in 1958.

In January 1957 Mr. Veryard was elected President of the Commission for Climatology of the World Meteorological Organization and he was largely

responsible for the successful meeting of the Commission held in London in December 1960. His many friends and colleagues wish him a well earned, long and happy retirement.

F. J. SCRASE, O.B.E., M.A., Sc.D.

Dr. F. J. Scrase, O.B.E., who retired from his appointment as Assistant Director (Instrument Development) in August 1957 and returned to serve as Secretary of the Meteorological Research Committee finally left the service of the Meteorological Office on 15 August 1961.

His studies were interrupted by service in the First World War from 1915 to 1919 in the Special Brigade of the Royal Engineers and as an examiner in the Aeronautical Inspection Directorate. He was awarded the B.A. degree of Cambridge University in 1920 and joined the Office as a Junior Professional Assistant in August of that year. After a few months at Kew Observatory he was seconded to the War Office Establishment at Porton and returned in 1926 to Kew where he served for a further ten years. In 1937 he went, on promotion to the grade of Senior Technical Officer, to take charge of the Meteorological Office in Gibraltar and in 1939, with further promotion, he returned as Head of the Instruments Division. He retained this position, at a variety of locations, with a variety of titles, but with ever-growing responsibilities, until 1957. He was appointed an Officer of the Order of the British Empire in 1948.

Dr. Scrase is essentially a reserved man. He has a sometimes unconventional sense of fun and his anecdotes, particularly those concerning his days at Porton, are occasionally enlivened by a startlingly salty phrase. He is sometimes willing to comment, with candour, on attainments of others, but he rarely speaks of his own. For this reason many who have had contact with him in the later part of his career did not realize they were dealing with a scientist of more than usual ingenuity and originality. His work at Porton included one of the first investigations of the statistical properties of turbulence; the ideas were identical with those which, ten years later, in one of the first manifestations of the electronic revolution, led to the establishment of the modern treatment of turbulence. At Kew Dr. Scrase first worked in the field of seismology and in two papers published by the Royal Society pioneered the investigation of deep-focus earthquakes. He turned his attention to atmospheric electricity and with a series of ingenious devices made continuous recordings of all the important electrical properties of the lower atmosphere at Kew. In collaboration with Sir George Simpson he made the first electrical soundings in thunderstorms with instrumented free balloons. For this work he was awarded the Cambridge degree of Sc.D. in 1939. He found time whilst running the Instrument Development Division to make scientific studies of the results of high-level balloon soundings, and he was responsible for the heat-transfer analysis which established the radiation corrections of the Meteorological Office radiosonde. He was rewarded for this work by the grant of the L. G. Groves Memorial Prize for Meteorology in 1955. Even after retirement his scientific work did not cease, and he is now engaged on a fruitful study of the measurements of the space gradients of magnetic fields as recorded at Lerwick Observatory during the International Geophysical Year.

We can be sure that Dr. Scrase will enjoy his retirement, and not in idleness. We wish him a long one.

MR. R. G. VERYARD

DR. F. J. SCRASE, O.B.E.

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A PRELIMINARY NOTE ON EARLY METEOROLOGICAL OBSERVATIONS IN THE LONDON REGION, 1680–1717, WITH ESTIMATES OF THE MONTHLY MEAN TEMPERATURES, 1680–1706

By G. MANLEY, M.A., D.Sc.

Professor of Geography, Bedford College, University of London

In September 1663 Dr. Wilkins read a paper to the newly-founded Royal Society, in which he advocated the keeping of "a history of the weather" as a desirable objective. As a result Robert Hooke, who was then Curator of Experiments, was commissioned to devise a scheme for the maintenance of daily observations. This he presented at a meeting on 7 October. The "scheme" that he proposed, with its table of nine columns including readings of the barometer and thermometer, was printed in Sprat's *History of the Royal Society* (1667). It was brought to the attention of a number of the early Fellows, and readers who wish to refer to it can find an illustration in Sir Napier Shaw's *Manual of Meteorology* (vol. I, p. 161).

Hooke was later asked to produce "a thermometer that should serve as a standard"; this he did at a meeting on 11 January 1665. Dr. Louise D. Patterson has discussed the significance of this early Royal Society's thermometer and has deduced the approximate value of the degree on Hooke's scale (*Amer. J. Phys.*, **19**, 1951; *Isis*, **44**, 1953).

As a result of Hooke's work quite a number of his contemporaries began to keep daily records, and several of these seventeenth-century meteorological journals giving instrumental readings exist. Hooke's own daily readings from March 1672 to May 1673 can be seen in his MS diary at the Guildhall Museum. John Downes, physician to Christ's Hospital, provides daily readings from March 1680 to September 1694 (MS, Sloane Collection, British Museum). I am not without hope of being able to effect a link between Hooke's and Downes' observations.

The barometer and thermometer were the most common instruments in use and both were for long very imperfect. These early thermometers seem for the most part to have been sizeable, two feet or more in length, with a large spherical bulb using spirit. They were unreliable, for apart from the fact that the scale reading was liable to change with time, as the glass was not annealed, the spirit was not standardized and the bore of the tube might be irregular. It is evident that Locke and other users were quite conscious of some of these defects. But instruments were few and no doubt much valued. Hence it is understandable that it became common practice to hang the thermometer within a room adjacent to and perhaps mounted with the barometer, probably also beside a window, but not directly affected by sunshine. Moreover, many of the early observers were physicians interested in the relationship between the weather and disease, which no doubt led them to think that the state of the air within the rooms in which men spend much of their working time was significant. The range of the readings indicates that contemporary rooms were, to say the least, well aired and no doubt the wide chimneys helped. Winter morning temperatures were quite commonly below 40°F. Examination makes it clear that such indoor observations can be sufficiently consistent to provide a basis for estimates of the trend of mean temperature, but hitherto there has not been opportunity to link them with outdoor readings.

The first observer who consistently kept his thermometer out-of-doors was the Reverend William Derham, F.R.S., at his rectory at Upminster, 15 miles east of the city. We have ten years of his daily observations, almost complete, from 1697 to 1706. For eight of these years, beginning in 1699, he gives us thrice-daily readings of a thermometer on a north wall, at fixed hours. The time of the early morning observation varied from 5h to 8h in different months; the other readings were consistently taken at noon and at 21h. Derham's observations for 1697–99 were printed in the *Philosophical Transactions of the Royal Society*; and from 1700–06 he continued to send his beautifully-kept MS tabulations to the Royal Society.

Recently by good fortune I have found in the Bodleian Library three manuscript meteorological journals whose existence has apparently not hitherto been recognized. Two of these are in the Rawlinson Collection; by what appears to be an accident in printing, they are not readily to be found in the catalogue. The third is the original meteorological journal kept by John Locke at various places at intervals between 1666 and 1703 throughout his active life. Some parts of Locke's journal were published; for example, his daily observations for several months in 1692 were printed in a short paper in the *Philosophical Transactions* for 1703. But the original MS journal provides a continuation for a great part of each of the years 1693–1703, during the eight months or thereabouts when he was in residence at Oates, 20 miles north-north-east from the City, near Ongar in Essex. Barometer and thermometer were read daily; the thermometer was by Tompion, and Locke had the misfortune to break it in March 1701. It is interesting to note that he did not obtain a new one until September. In 1725 we likewise learn that Dr. Huxham at Plymouth had to wait for more than two months for a replacement to arrive from London.

The other newly-discovered MS journals are non-instrumental. The first (Rawlinson 662D) gives daily observations of weather from January 1669 to December 1700; with wind directions from May 1673 onward. No author is named; but I was struck by the resemblance of the wording to that used by Gadbury. Comparison of the handwriting with other MS known to be by him confirmed that this MS is in Gadbury's own hand and is very nearly identical with that which formed the basis of the printed journal, giving daily observations from November 1668 to December 1689, in Gadbury's *Nauticum Astrologicum* (1691; another edition, 1710). This last was discussed by E. L. Hawke (*Weather*, **3**, 1948). The value of this manuscript lies in the fact that it provides eleven further years (1690–1700) of consistent daily observations for London.

The second MS (Rawlinson 1161D) is written up in a sizeable book, about $13 \times 9 \times 2$ in. On each left-hand page we find a variety of astronomical entries; on the right-hand, an entry of each day's weather, virtually complete from June 1699 to November 1717. There is a column giving "The air's weight" from which a table of pressures might possibly be compiled. Wind direction is also commonly mentioned. The journal ends rather suddenly; many of the later pages were unused.

There is absolutely no indication of the observer's name or of his exact place of residence. But there are many scattered entries reporting the weather at various places on the main roads leading from London; for example, Maidenhead, Dunstable, Barnet and Braintree are mentioned and sometimes London

itself. The weight of the evidence suggests that the observer resided in Middlesex, west of London, not very far from the Thames, and probably on or near a main road where he could pick up comments from passing travellers. But from 1705 to 1709 the journal is extremely hard to read as the ink has become absorbed and much blurred. The quality of the observations is quite good, testifying to an observer who was very fairly alert to the meteorological events of the day. I have taken out comparisons of entries relating to rain, snow and thunder against Gadbury, Derham and Locke. From these it appears that this anonymous observer was quite up to Derham's standard in regard to rain, and about equal to Gadbury. He was rather better than Derham in regard to his observations of the occurrence of snow. Over the years 1713–17 his entries can also be compared with those in Smith's well known Richmond journal; it is clear that he was much more alert, with about 25 per cent more rain days and nearly double the number of snow days. Smith is confirmed as a rather casual observer when we compare his entries with those in later journals, for example those kept by Jurin and Hooker.

The really valuable feature of this journal is that for the first time we have a complete run of daily observations through 1707 to 1713. This completes the series of links through which it now becomes possible to provide a meteorological comment on the weather in the London region for every day since November 1668.

Deductions with regard to the meteorology of the period 1680–1720.— These several journals are now being collated and a preliminary summary can be given of the deductions that can be made from them, more especially in regard to the trend of mean temperatures and the frequency of occurrence of rain and snow. The intrinsic interest of this period, from the meteorological standpoint, is very great. There is widespread evidence that the last decade of the 17th century was marked by a predominance of cool unsettled weather over much of northern Europe. In England, the high price of corn was recorded in the phrase "King William's dear years"; in Scotland, the "seven ill years" were catastrophic; in Sweden, late springs and bad harvests were frequent; and in the Alps, Scandinavia and Iceland the glaciers advanced generally, until some time between 1715 and 1720.

With regard to temperature, in order to derive a series of estimates of monthly means, Derham's series of eight years of observations of an outdoor thermometer on a north-facing wall was carefully analysed. It is to be noted that there exists no direct method of overlapping these earlier records with the later London temperature observations which begin in November 1722. A very tenuous link exists through the early Dutch observations kept by Cruquius at Delft. These begin in January 1706 and run on to 1734; they have been reduced to present-day standards by Labrijn (*Meded. ned. met. Inst.*, **49**, no. 102, 1945).

Derham read his thermometer at an early morning hour soon after sunrise. His later observations were at noon and 21h. The graduations of his thermometer were in tenths of an inch, and during these eight years the range, on his scale, lay from 58 to 182 at the observing hours, the freezing-point being 82. On twenty-two days however he gives an additional mid-afternoon reading. These were as we might expect days of unusual warmth for the season, and the highest reading he reports is 186. We have no exact knowledge of the value of

his degree, as we do not know an upper fiducial point. Hence we must deduce the probable equivalent by other means. Further, we are not fully informed with regard to details of the exposure.

From what we know of the range of temperature on a north wall in south-east England, for example from the properties of the old Kew screen, a beginning can be made by assuming that over eight years the highest temperature would approximate to 90°F. On such an assumption Derham's degree would equal 0·56°F. For example, the mean annual maximum over 30 years at Camden Square (1926–55) was 89·8°F. At Kew (1871–1921, *The book of normals*) in the old north-wall screen we have 85°F and at Cambridge (1876–1921) 87°F, the absolute extremes being respectively 94°F and 96°F. We can also refer to the published average hourly values of the shade temperature in each month for Kew, and also those for the old Glaisher stand at Greenwich. From these one can take out the mean difference to be expected in each month between shade temperatures observed at the hours used by Derham.

Analysis of the observations however, using the above approximate conversion, makes it clear that the mean daily range of temperature over the interval from early morning to noon, and from noon to 21h, was greater than that we now expect, not only in the north-wall screen at Kew, but even on the Glaisher stand at Greenwich. Moreover the consistent increase in the differences from January to July makes it evident that we are most probably dealing with a thermometer exposed, at noon, to reflected radiation, probably from an adjacent wall. Derham gives us no details, but his mean noon temperature in the summer months on this assumption comes out very similar to that observed on the old Greenwich Glaisher stand. The lowest fixed-hour reading in the early morning, 19°F, and the average lowest reading, 22°F, compare quite well with what one would expect on a fairly sheltered wall during a period of eight years over which there are no contemporary accounts of very excessive heat or cold. Upminster moreover is not so located as to be subject to unusually low winter minima. At Cambridge the average annual extreme minimum is given in the old *Book of normals* as 15°F, and at Kew (in the north-wall screen) as 20°F.

After a number of trials making various assumptions with regard to the behaviour of the thermometer, it seemed most reasonable to avoid using the noon observations and to take out a first approximation to the monthly means by using the early morning and 21h readings, and correcting them to a mean for the day, using the corrections that were found to be applicable to readings made at the stated hours on the Glaisher stand at Greenwich.

Over a period of ten years or so, an independent check on the overall mean temperature of the six colder months, November–April inclusive, can be derived from the average annual number of days with snow or sleet observed to fall (cf. Manley, *Quart. J.R. met. Soc.*, **84**, 1958). While the period of eight years, 1699–1706, is rather short, we can check the frequency of occurrence of days with snow from more than one source, and we find that the average annual total was appreciably higher than today and indeed is comparable with that of late Victorian times. Accordingly the mean temperature of the colder half of the year should be expected to be about.1°F lower than it is today.

In adopting a conversion factor for Derham's degree we have therefore two

criteria to satisfy. In the first place the amplitude of the range of temperature on Derham's thermometer is such that his instrument was clearly affected by reflected radiation. Hence one would expect that in the summer months his mean noon temperature, and likewise his absolute maxima, would be rather higher than the value initially assumed. Noon temperatures in summer actually average about 3°F higher than one would expect in relation to the morning and evening readings.

The second criterion is that the overall mean for the six winter months should be lower than it is today. These criteria are satisfied if we take the equivalent of Derham's highest reading in eight years to be 93°F so that the consequent value of his degree becomes 0·59°F. In turn, this implies a corresponding adjustment of the initial approximations to monthly means derived from the morning and evening observations. I find no clear-cut ratio between Derham's degree and others, save that Derham's degree appears to be approximately 5/6 of Hauksbee's degree. I also carried out some experimentation with the Fahrenheit equivalent of Derham's lowest summer daytime temperatures on cloudy days, comparing them with what we know of the extremes in the last 100 years, with satisfactory results. Lastly, the summer of 1706 was slightly warmer than the present-day normal in Holland, and on the above adjustment it likewise proved to be slightly above normal in Essex.

The observations before 1699.—Locke's indoor thermometer readings overlap those of Derham, and between 1692 and 1703 we can work out, by comparing months of the same name in different years, approximate means for most of the cooler months of the year. For the remaining summer months, when Locke was away, we can but make estimates. Here the Gadbury MS is useful; for example it is very noticeable how frequently during July and August 1695 he uses the adjective "cold" by comparison with the same months in other years. For the greater part of 1693 we can also compare Hunt's daily readings of a thermometer in London (given by Halley, *Phil. Trans.*, **18**, 1694).

In turn, Downes' indoor readings, March 1680–September 1694, overlap those of Locke. Unfortunately there is an interruption of the sequence of daily readings for two months of 1691, probably on account of a breakage as the later values are out of step. Hence, from 1680 to 1691 we have no overlap with the later Locke series at all, and there is evidence that Downes' thermometer changed its zero very considerably (by about 15°F) and not in a linear manner. Some indication of the rate of change during that period can be got by comparison with scattered observations by Locke during 1681–83.

The monthly means given below represent the best interpolation, based on a careful analysis together with the likelihood that no one monthly mean during those twelve years would lie seriously outside the extreme values observed in the London area since 1800. Moreover, the overall mean temperature of the six colder months falls into line with expectations based on Gadbury's observed frequency of days with snowfall, which over the twelve years averaged nearly half as much again as we should expect today. Gadbury's record is consistent in this respect and the good quality of his record is corrobated when comparison is made with the overlapping observations by Downes, and also by Ashmole at Lambeth.

The prolonged severe cold of the famous winter of 1683–84, with its brief spells of thaw, is very well supported by the contemporary accounts of the

remarkable duration of ice on the Thames. There seems little doubt that this winter (December–February), with a mean temperature of about 30·3°F in the London area, ranks as colder than any subsequent winter, for example 1740, 1814 or 1879. The exceptional mildness of the winter of 1686 is also well documented. The whole series of years shows a wide range of behaviour; for example there were three decidedly warm Mays and three exceptionally cold Septembers, two very warm Octobers and two very cold. The deductions appear to be well supported by contemporary descriptive notes of the seasons.

Summary

(*a*) *Precipitation*.—Given a careful observer, the average annual total of days with "precipitation observed to fall" is clearly in good general agreement with the present-day total of days with 0·01 inch or more measured. In Table I

TABLE I—AVERAGE NUMBER OF "DAYS WITH PRECIPITATION" AND "DAYS WITH SNOW OBSERVED TO FALL"

	No. of days with precipitation		No. of days with snow observed to fall
1921–1950	approx. 168 (0·01 in. or more)		12·5 (good, but not continuous observation)
1671–1680	155		17·2
1681–1690	167	rain, snow,	18·2
1691–1700	179	or	25·5
1701–1710	(168)	drizzle	(17·9)
1711–1720	(165)		(20·0)

I have summarized the averages by decades, from 1671 to 1720. For the years 1718–20 the estimates are derived by adjustment from the rather less "alert" record maintained by Smith at Richmond.
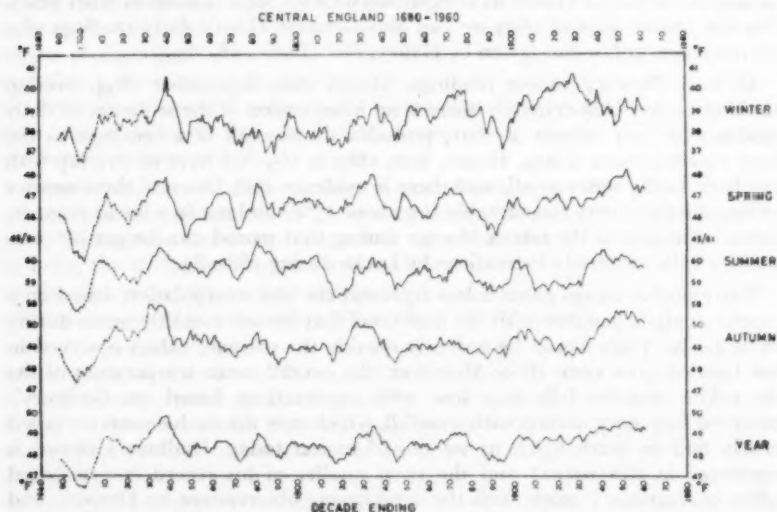

CENTRAL ENGLAND 1680–1960

FIGURE I—DECADAL RUNNING AVERAGES OF SEASONAL AND ANNUAL MEAN TEMPERATURES FOR CENTRAL ENGLAND, 1680–1960

It will be seen that the decade 1691–1700 was not only distinctly more unsettled than those before and after. The snow frequency was about twice that we should expect today. All the indications are that this decade was notably characterized by cold unsettled weather in spring and by cool and on the whole rainy summers. These deductions are in keeping with all contemporary descriptive reports, such as those in Evelyn's later diary. We may also note that in this decade there was a decided increase in the amount of ice in the northern Atlantic. According to Koch (*Medd. Grønland*, **130**, 1945), during the summer of 1695 drift-ice was observed all around the coasts of Iceland.

In England, 1695 must rank as one of the coldest years ever known, comparable with 1879. An extremely snowy and very prolonged winter, during which the Thames was frozen over, was followed by a chilly spring and a very cool and wet July and August; the later autumn however was relatively mild.

TABLE II—ESTIMATES OF THE MEAN MONTHLY TEMPERATURE (°F) IN THE LONDON REGION, 1680–1706

These estimates are primarily based on Derham's Upminster record, 1699–1706, partially overlapped by Locke's incomplete record, 1692–1703. Earlier years are less reliable, as there is no satisfactory overlap with the later records. Estimates for this period, and for Locke's missing months (in brackets) have taken into account the daily observations of wind and weather in other contemporary journals, and are given to whole degrees only (1699 onward to 0·5°).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1680	(41)	(39)	(43)	45	52	57	63	61	60	52	45	34	49·3
1681	34	36	40	48	53	59	61	63	59	54	45	38	49·2
1682	44	37	41	45	55	59	61	60	57	51	43	43	49·7
1683	39	37	43	51	55	63	62	58	57	45	41	33	48·7
1684	27	31	38	45	57	61	63	62	56	53	38	40	47·6
1685	34	39	42	49	56	60	59	60	55	54	46	44	49·8
1686	45	44	46	49	56	62	63	60	57	50	45	43	51·7
1687	39	41	41	45	54	57	62	61	53	53	44	43	49·4
1688	39	36	39	43	53	57	62	60	55	46	40	38	47·3
1689	34	41	42	48	53	56	62	61	57	48	42	41	48·7
1690	40	41	41	48	51	57	62	61	56	49	45	41	49·3
1691	35	35	42	45	52	58	61	62	54	(50)	(42)	39	47·9
1692	37	32	40	47	50	58	61	61	54	45	42	39	47·2
1693	38	42	38	45	50	60	61	61	55	51	44	38	48·6
1694	33	42	39	47	50	57	61	57	52	(47)	43	(37)	47·2
1695	31	33	39	43	50	(57)	58	(57)	(54)	50	(43)	40	46·2
1696	43	41	39	43	53	(57)	(62)	(62)	(55)	(50)	(43)	37	48·7
1697	35	34	43	46	55	57	(62)	(60)	(56)	(50)	(40)	37	47·8
1698	33	34	39	47	49	56	61	(61)	(57)	(50)	40	39	47·2
1699	38·5	39	40·5	45	51·5	60·5	65·5	61	58	50·5	42·5	39	49·3
1700	40	37·5	39·5	45	55·5	58·5	61	61	57·5	49·5	41·5	40	48·9
1701	38	37·5	38	41	53	59·5	67·5	63	60·5	47	44·5	39	49·0
1702	42	45	44	44·5	52·5	58	61	63	60	51·5	41	40·5	50·3
1703	36·5	40	43·5	49	55	59	63	63	52·5	47	46	42	49·7
1704	36·5	38·5	43	49	54	60	64	64·5	55·5	48·5	44·5	39	49·7
1705	37	39·5	41	47·5	53·5	56	62	65·5	55·5	49·5	40	40·5	49·0
1706	37·5	40·5	45	50	55·5	62	63	64	56·5	53·5	44	41	51·0
1681–90	37·5	38·3	41·3	47·3	54·3	59·3	61·7	60·6	56·2	50·3	42·8	40·4	49·1
1691–1700	36·3	37·0	39·9	45·3	51·5	57·8	61·3	60·4	55·2	49·3	42·1	38·5	47·9
1701–10	37·9	38·5	42·4	47·4	54·2	59·6	62·7	63·4	57·7	49·7	44·6	40·5	50·0

For the years 1707–10 approximations are based on Dutch monthly means, adjusted by reference to contemporary English accounts.
Probable values at Upminster today, based on *rural* stations around London:

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1921–50	39·9	40·3	43·8	48·3	54·1	59·8	63·4	62·7	58·5	51·3	44·4	40·4	50·6

(b) *Temperature.*—In Table II all statistics have been drawn up with reference to the New Style, or Gregorian, calendar months in order to assist

comparison with present-day conditions, and with contemporary events in France and other European countries in which the Gregorian calendar was already adopted. In Figure 1 I have used these averages to provide an extension of the series of ten-year running mean temperatures representative of the four seasons for "central England". This will serve to demonstrate the decided recession in the 1690's, followed by the well documented amelioration about 1730. It is hoped that the estimates of the monthly means here given will prove of service, at least as an indication of trend, until such time as further confirmation can be forthcoming. If my interpretation of the probabilities based on the frequency of snow is correct, the monthly means do not appear likely to err by more than 1°F. Primitive though these instrumental observations are, they appear at present to be the earliest series of any length in Europe, which renders the attempt to reduce them to modern standards the more alluring. Further work on these journals is in progress.

THE PROBLEM OF FORECASTING THE DOWNWARD PENETRATION OF SNOW

By F. E. LUMB, M.Sc.

Summary.—During continuous moderate precipitation, if the lapse rate is close to the saturated adiabatic, snow can be expected to penetrate down to the level at which the wet-bulb temperature is $1.5°C$, but is very unlikely to descend beyond the $3.5°C$ wet-bulb level. Even during heavy precipitation, snow will very rarely descend beyond the $4.5°C$ wet-bulb level. By means of a simple geometrical construction on the tephigram, the potential depth of penetration of snow for any known environment curve can be found.

Introduction.—A difficult problem which sometimes faces the forecaster in winter over the British Isles, when continuous moderate or heavy precipitation is expected, is to decide whether the precipitation will be in the form of rain or snow. A reliable forecasting rule is that if the $0°C$ wet-bulb level is less than 300 metres above the ground, continuous moderate precipitation will very probably be in the form of snow. In other words, snow can be expected to descend to the $1.5°C$ wet-bulb level if the wet-bulb lapse rate below the $0°C$ level is the saturated adiabatic (γ_s). There is, however, as yet no well established rule for forecasting the lowest level to which snow can be expected to descend during moderate or heavy precipitation. The unexpected snowfall over the Cotswolds on 1 November 1942 has been taken as evidence that it is possible for snow to descend as much as 1500 metres below the $0°C$ wet-bulb level, but this is based on the assumption that in the absence of surface fronts over southern England on that day, the $0°C$ level given by the Larkhill upper air sounding at 1100 GMT was applicable to the Cotswolds, only 80 kilometres to the north. However, a detailed examination of this snowfall by Lumb[1] has revealed that the above assumption was erroneous and it is most unlikely that snow penetrated downwards more than 600 metres below the true $0°C$ wet-bulb level.

Evidence is presented in this paper which shows that 600 metres can be taken as an upper limit to the depth of penetration of snow during precipitation whose equivalent rate of rainfall is light or moderate (that is, does not

exceed 4 millimetres per hour), provided the lapse rate is close to the saturated adiabatic (γ_s). In other words, a reliable forecasting rule is that during moderate precipitation snow will not descend below the 3·5 °C level if the lapse rate below the 0°C level is γ_s. Also, it will be shown how a simple construction on a tephigram enables the lowest level of penetration of snow to be found, whatever the wet-bulb environment curve below the 0°C level may be, provided it is known accurately.

Lamb[2] has related the type of precipitation to 1000–500-millibar thickness, and Murray[3] has assessed the probability of precipitation being in the form of snow when certain pairs of parameters (1000–500-millibar thickness and surface temperature, 0°C level and surface temperature) are known. Mineeva[4] has made a similar study using the 1000–850-millibar thickness and the surface temperature. A knowledge of critical thickness values, in conjunction with 24-hour thickness charts, is useful in alerting the forecaster to the possibility of snow, but in order to make a more confident short-period prediction, it is necessary to consider the thermodynamical aspects of the problem, in particular the role of the falling snowflakes as a powerful cooling agent. Both cooling by evaporation and by melting are involved.

Cooling by evaporation.—It is a matter of common experience that cooling by evaporation during precipitation of moderate intensity can reduce the wet-bulb depression to a small fraction of its original value within an hour or two. The rate of cooling at any level decreases exponentially with time, and if the air below the 0°C level is dry there will be a rapid fall of temperature during the first hour. A column of air which has been subjected to at least two hours cooling by moderate precipitation will be saturated or very nearly so, and the temperature at any level will have been reduced practically to the wet-bulb temperature. An example of a snowfall which clearly demonstrates the importance of cooling by evaporation will be given later.

Cooling by melting.—Even when the 0°C wet-bulb level is several hundred metres above the ground, the possibility of snow reaching the ground cannot be ignored. Snowflakes of large mass can extend downwards several hundred metres below the 0°C level before being completely melted. The rate of cooling by melting is zero at the 0°C level and falls to zero at the level below which all snowflakes have completely melted. It is most rapid at some intermediate level within the melting layer so that in the lower part of this layer the lapse rate tends to increase, but the process of cooling by melting in the free atmosphere is strongly counteracted by convection, especially if the air is saturated. However, if a substantial amount of falling snow (in the form of partly melted snowflakes) reaches the ground, convection ceases, and the subsequent cooling of the whole column of air between the 0°C level and the ground by the melting of the falling snow can quickly reduce the temperature of the whole layer to 0°C, and precipitation then takes the form of snow at all levels down to the ground. This process was well illustrated by the Cotswolds snowfall of 1 November 1942, examined by Lumb[1], and by the New England snowfall of 13 April 1953, studied by Wexler, Reed and Honig[5]. In the former example, snow penetrated downwards 600 metres below the 0°C wet-bulb level and the precipitation changed from rain at a temperature of 2·8°C to snow at 0°C within a period of three hours. In the latter example, snow penetrated downwards between 700 and 750 metres below the 0°C wet-bulb level and precipitation changed from rain at a temperature of 4·4°C to snow at 0°C within a period of one hour.

Cooling by melting is most effective when prolonged precipitation is associated with light winds below the 0°C level, as in the case of the Cotswolds snowfall of 1 November 1942, or when the trajectory of the layers of air is such that they are subject to several hours' cooling in the precipitation belt, as occurred in the New England snowfall. It has little effect over the sea, and with onshore winds a coastal strip will escape the snowfall which may occur farther inland.

Depth of penetration of snow.—Experience shows that the fall of surface air temperature towards 0°C starts at about the time when the observed form of precipitation changes from rain to sleet.* It is therefore important to know the greatest depth (D) below the 0°C level in a saturated environment at which the form of precipitation can be readily recognized by an experienced observer as being in the form of sleet, since D is also the potential depth of penetration of snow.

D will depend on the temperature and humidity of the environment below the 0°C level, and on the intensity of the precipitation. For any given snowfall it can be shown theoretically (see Appendix, p. 316) that in a saturated environment

$$\int_{p_0}^{p_D} T_a \, d(\log p) = \text{constant}, \qquad \cdots (1)$$

where p_0 is the pressure at the 0°C level, p_D is the pressure at a depth D below the 0°C level and T_a is the temperature (in °C) of the environment. The integral of equation (1) is proportional to the area on the tephigram contained between the environment curve, the 0°C isotherm and the p_D isobar. Equation (1) therefore means that this area is constant for any given snowfall, whatever the environment curve. An example of the application of equation (1) to a particular environment curve will be given later. If z is the vertical distance below the 0°C level, for a constant lapse rate γ equation (1) becomes

$$\gamma \int_{0}^{D} z \, dz = \text{constant}. \qquad \cdots (2)$$

D will also depend on the melted drop-size spectrum of the snowfall, since the greater the mass of a snowflake, the greater its melting depth. Gunn and Marshall[6] have shown that in general the melted drop-size spectrum during snowfall broadens as the intensity of precipitation (I) increases. Consequently a positive correlation between z and I is to be expected.

Since over the land during continuous precipitation in maritime polar air, the lowest layers of the atmosphere are saturated or very nearly so, and the lapse rate is usually close to the saturated adiabatic (γ_s), it is of special importance to find an upper limit to the depth (D_s) of penetration of sleet (as an observable phenomenon) downwards in a saturated environment which has a lapse rate γ_s.

Over land, except in the rare circumstance that the start of an upper air sounding coincides with an observation of sleet, the lapse rate below the 0°C level is not known accurately. However, over the sea when sleet is reported, a

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* Throughout this paper, the word "sleet" means "precipitation in the form of raindrops and melting snowflakes".

combination of heating from below by the relatively warm sea surface and cooling from above by thawing snowflakes, will ensure that the lapse rate is close to the dry adiabatic (γ_d) from the level of observation (about 10 metres above sea level) up to the cloud base, and close to γ_s in cloud.

If h_b is the height of the cloud base and h the height of the $0°C$ level, then assuming saturation at all levels, from equation (2) we have

$$\gamma_s \int_0^{h-h_b} z \, dz + \gamma_d \int_{h-h_b}^h z \, dz = \gamma_s \int_0^{D_s} z \, dz \quad \text{if } h > h_b \qquad \dots \dots (3)$$

and

$$\gamma_d \int_0^h z \, dz = \gamma_s \int_0^{D_s} z \, dz \quad \text{if } h < h_b. \qquad \dots \dots (4)$$

Integrating equation (3), we find

$$D_s^2 = (h-h_b)^2 + \alpha h_b(2h-h_b), \qquad \dots \dots (5)$$

where $\alpha = \dfrac{\gamma_d}{\gamma_s}$.

Also if T is the surface air temperature in degrees C,

$$h = h_b(1-\alpha) + h_s \qquad \dots \dots (6)$$

where $h_s = \dfrac{T}{\gamma_s}$.

Eliminating h from equation (5) by means of equation (6), we get

$$D_s = (h_s^2 - \alpha(\alpha-1)h_b^2)^{\frac{1}{2}} \quad \text{if } h > h_b \qquad \dots \dots (7)$$

and from equation (4) we get

$$D_s = \dfrac{h_s}{\alpha^{\frac{1}{2}}} \quad \text{if } h < h_b. \qquad \dots \dots (8)$$

In practice the air below the cloud base is not saturated. Heat transfer theory shows that the contributions of conduction and condensation to the rate of melting are approximately equal. Hence by assuming a constant rate of decrease of the wet-bulb depression from the ship's observation level to zero at the cloud base, a correction (usually small) can be made to equation (7) or (8) to take account of the deviation from saturation. If T_w is the ship's wet-bulb temperature, and $T' = \frac{1}{2}(T + T_w)$, the modified form of equation (7) is

$$D_s = [(h_s')^2 - \alpha'(\alpha'-1)h_b^2]^{\frac{1}{2}} \qquad \dots \dots (9)$$

and the modified form of equation (8) is

$$D_s = \dfrac{h_s'}{(\alpha')^{\frac{1}{2}}} \qquad \dots \dots (10)$$

where $h_s' = \dfrac{T'}{\gamma_s}$ and $\alpha' = \alpha\left(1 - \dfrac{T-T'}{h_b\gamma_d}\right).$

If T, T_w and h_b are known, D_s can be calculated from equation (9) or (10) as appropriate. Hence, with the aid of these equations, observations of moderate or heavy sleet (present weather, ww $=69$) over the sea can be used to find the upper limit of D_s, that is, an upper limit to the potential depth of penetration of snow over the land during continuous moderate or heavy precipitation when the lapse rate below the 0°C level is the saturated adiabatic (γ_s).

Thirty-three occasions of ww $=69$ at the North Atlantic ocean weather stations have been found. As regards h_b, it is very difficult for an observer at sea to give an accurate estimate or measurement of the height of the cloud base during moderate or heavy precipitation. However, ignoring five cases of "sky obscured", the reported cloud base ranged from 400 to 3000 feet, the median value being 800 feet. Taking h_b to be 400 feet (122 metres) and 800 feet (244 metres) respectively, and using equations (9) or (10) as appropriate to calculate D_s, Table I is obtained.

TABLE I—VALUES OF D_s FOR ASSUMED CLOUD BASES
OF 122 AND 244 METRES

D_s metres	Assuming $h_b = 122$ metres	Assuming $h_b = 244$ metres
	number of occasions	
400	22	23
400–500	6	6
500–600	4	3
600–700	0	0
700–800	1*	1†

*$D_s = 724$ m.   †$D_s = 708$ m.

It is significant that the one case when D_s exceeded 600 metres (station ALFA at 0900 GMT on 9 November 1956) was the only occasion when the cloud type was reported as being of convective origin, namely, cumulonimbus. Orographic influences being absent over the sea, it is unlikely that the intensity of precipitation would qualify for the description "heavy" except perhaps on 9 November 1956. Since for any given values of T and T_w, D_s increases as h_b decreases, Table I shows that D_s is very unlikely to exceed 600 metres during precipitation of moderate intensity. In other words, over land snow is very unlikely to descend below the $3 \cdot 5$°C wet-bulb level when the lapse rate below the 0°C level is the saturated adiabatic and the equivalent rate of rainfall is moderate.

It will be shown that this limit of $3 \cdot 5$°C was closely approached during two of the most striking examples of downward penetration of snow on record for the British Isles.

South Midlands snowfall of 28 December 1945.—A rapidly deepening depression moved quickly east-north-east over southern England during the day. The upper air sounding for Downham Market (Figure 1) at 0001 GMT is representative of the surface layers of the air through which snow subsequently penetrated down to the ground. Although the 0°C level was as high as 890 millibars and the temperature in the surface layers was above 5°C, nevertheless, over a belt of country to the north of the track of the centre of the depression, after several hours of rain and sleet, snow penetrated down to ground level and reached ground only 100 metres above sea level to the north of the Thames basin.

What is the explanation? The main contributory factor was undoubtedly the relative dryness of the air mass. Cooling by evaporation would quickly lower the temperature at almost all levels by 2° to 3°C. The rapid fall of pressure was

also a very important factor. Mean-sea-level pressure in the snow belt fell 15 millibars below that at Downham Market at 0001 GMT. This would result in the lowering of any given isobaric surface by about 120 metres, and reduce the wet-bulb temperature in the lowest layers by about 0·5°C. Under the combined influence of cooling by evaporation, adiabatic expansion, and convection, the environment curve below the 0°C level would be modified to the shape AB in Figure 1, that is, there would be a nearly constant lapse rate very close to γ_s.

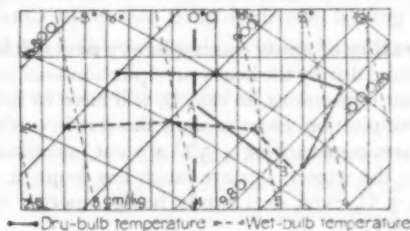→ Dry-bulb temperature ←---← Wet-bulb temperature

FIGURE 1—TEPHIGRAM FOR DOWNHAM MARKET, 0001 GMT, 28 DECEMBER 1945

In the snow belt, the snow penetrated down to the 980-millibar level, that is to the level where the temperature although originally as high as 6·5°C had fallen to 3·5°C under the combined influences of evaporation and adiabatic expansion. At North Weald, for example, at 0900 GMT, just before rain changed to snow, the dry-bulb and wet-bulb readings were both 38·0°F (3·3°C).

An examination of relevant rainfall records (for example, Bristol, Upper Heyford, Hampstead) shows that to the north of, but near to, the centre of the depression, the rate of rainfall was generally between 3 and 4 millimetres per hour, that is, near to the upper limit of moderate intensity.

Cotswolds snowfall of 1 November 1942.—Lumb[1] has given evidence to show that the environment curve below the 0°C level at Little Rissington on 1 November 1942, when sleet penetrated down to the ground, was as shown in Figure 2 (curve ABC). The air was saturated, and the lapse rate was very close to γ_s above 950 millibars but approximately isothermal below. By equation (1), if in Figure 2 the saturated adiabatic AB is produced to the level D, such that area BED = area $PQCE$, D is the level to which the snow would have reached if there had been a constant lapse rate γ_s. We see that the wet-bulb temperature
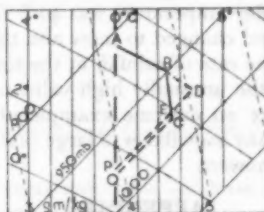

FIGURE 2—TEPHIGRAM (SATURATED AIR) FOR LITTLE RISSINGTON, 0740 GMT, 1 NOVEMBER 1942

This was deduced from the Larkhill sounding for 2000 GMT, 1 November 1942

at the level D on the saturated adiabatic is about $3 \cdot 5°C$. The rate of rainfall at the time when the form of precipitation changed from rain to sleet was between 3 and 4 millimetres per hour, that is near to the upper limit of the moderate range.

The construction on the tephigram shows that the presence of the isothermal layer enabled the snow to penetrate about 5 millibars lower than it would have done if there had been a constant lapse rate γ_s. The influence of the isothermal layer was therefore small, but probably crucial in permitting sleet (potentially snow) to reach the ground over the highest part of the Cotswolds.

Depth of penetration of snow during heavy precipitation.—Snowflakes of largest mass are found during the heavy precipitation associated with instability showers and polar air depressions, so that D_s will have its largest values during heavy instability precipitation. Sleet or snow showers in conjunction with ships' dry-bulb temperatures approaching $4 \cdot 5°C$ are not uncommon over the north-east Atlantic during the winter, but are much less frequent when the air temperature exceeds $4 \cdot 5°C$, even sleet rarely being reported when the air temperature exceeds $5 \cdot 5°C$.

Twenty-seven cases of sleet or snow showers at ocean weather stations ALFA, INDIA and JULIETT have been found for which the ships' dry-bulb temperature was $\geqslant 40 \cdot 0°F$ $(4 \cdot 4°C)$. The reported cloud base for these occasions ranged from 1000 to 2000 feet. Accepting the reported cloud base to be a good estimate of the true cloud base, and using equation (9) or (10), as appropriate, Table II is obtained for D_s.

TABLE II—VALUES OF D_s USING REPORTED CLOUD BASES

D_s metres	number of occasions
600	12
600–700	8
700–800	2
800–900	2
900–1000	3

D_s exceeded 750 metres on only five occasions. Hence, even when there is heavy instability precipitation, the depth of penetration of snow is very unlikely to exceed 750 metres. This corresponds to the $4 \cdot 5°C$ level when the lapse rate is γ_s.

This limit was very closely approached during the remarkable snowstorm over New England on 13 April 1953 when sleet, changing quickly to snow, reached the ground when the temperature was $40°F$ $(4 \cdot 4°C)$. Within one hour the form of precipitation had changed to snow and the temperature had fallen to $32°F$ $(0°C)$. However, the rate of rainfall at the time when rain changed to sleet had on this occasion the unusually high value of 8 millimetres per hour. This snowfall was therefore an extreme example of downward penetration, and evidently contained many snowflakes of large mass which are characteristic of heavy instability snow showers.

APPENDIX
The melting of snowflakes in a saturated atmosphere

Mason[7] has calculated the distance which hailstones have to fall in saturated air before completely melting, on the assumption that all melt water is retained and uniformly distributed around the ice. The basic equations governing the

transfer of heat between the air and the hailstone (assumed to be spherical) are:

$$-L_f 4\pi a^2 \rho_l \frac{da}{dt} = 4\pi a b K_w \frac{T_s}{b-a}$$

(latent heat of melting) = (transfer through water)

$$= 4\pi b K_a C (T_a - T_s) + L_v 4\pi b D C [\rho_s(T_a) - \rho_s(T_s)] \quad \ldots \text{(1)}$$

= (conduction through air) + (condensation on surface)

where

a	is the radius of the unmelted core
b	is the overall radius of the particle
T_s	is the surface temperature (°C) of the hailstone
T_a	is the temperature (°C) of the environment
L_f, L_v	are the latent heats of fusion and evaporation
K_w, K_a	are the thermal conductivities of water and air
D	is the diffusion coefficient of water vapour in air
ρ_l	is the density of the ice particle
C	is a ventilation coefficient (a function of the Reynolds number)
$\rho_s(T_a), \rho_s(T_s)$	are the saturation vapour densities appropriate to the temperatures T_a and T_s.

In contrast to hailstones, snowflakes are of low density, and as they melt the melt water will tend to percolate into the ice portion. It is therefore reasonable to assume that the surface of the snowflake consists of a mixture of ice and water whose temperature remains at 0°C, that is, for a melting snowflake $T_s = 0°C$ and the term in equation (1) referring to transfer through water can be disregarded.

Equation (1) applies to a spherical particle, but snowflakes do not conform to any simple geometrical shapes. However, the term which represents the latent heat of melting can be brought into a more general form which does not assume any particular geometrical shape for the snowflake by writing it as $L_f m_0 \, dF/dt$, where m_0 is the mass of the snowflake at the 0°C level and F is the fraction of m_0 which has melted at any time. Similarly, the terms for conduction and condensation can be generalized by substituting the symbol S for $4\pi b C$, where S is a function of the size, shape and physical structure of the snowflake.

Equation (1) then becomes

$$L_f m_0 \frac{dF}{dt} = S[K_a T_a + L_v D\{\rho_s(T_a) - \rho_s(0)\}] \qquad \ldots \text{(2)}$$

For the small range of temperature with which we are concerned (0° to 5°C), as a good approximation we can write $\rho_s(T_a) - \rho_o(0) = \beta T_a$ where β is a constant.
Hence equation (2) becomes

$$L_f m_0 \frac{dF}{dt} = S(K_a + \beta L_v D) T_a. \qquad \ldots \text{(3)}$$

317

Putting $dt = dz/w$, where w is the speed of fall of the snowflake at any instant and z is measured downwards from the 0°C level, and writing

$$k = \frac{L_f}{K_a + \beta L_r D}$$

equation (3) becomes

$$k \, m_0 \frac{w}{S} \, dF = T_a \, dz. \qquad \qquad \cdots (4)$$

Now for any given snowflake w and S are both determined at any time by the changing shape, size and physical structure of the snowflake as it gradually melts into a raindrop. Hence w and S at any time are determined by their values at the 0°C level (w_0, S_0) and by F. Since w_0 is also determined by S_0, equation (4) can be written

$$k \, m_0 \, \phi \, (S_0, F) \, dF = T_a \, dz. \qquad \qquad \cdots (5)$$

Integrating from the 0°C level to the level (d) of completion of melting,

$$k \, m_0 \int_0^1 \phi(S_0, F) \, dF = \int_0^d T_a \, dz. \qquad \qquad \cdots (6)$$

For a given value of S at the 0°C level, that is S_0, ϕ is a continuous function of F only. Hence for any given snowflake

$$\int_0^d T_a \, dz = \text{const.} \qquad \qquad \cdots (7)$$

Since we are concerned only with a small range of temperature (5°C), equation (7) can be written

$$\int_{p_0}^{p_d} T_a \, d(\log p) = \text{const}, \qquad \qquad \cdots (8)$$

where p_0 is the pressure at the 0°C level and p_d is the pressure at a depth d below the 0°C level.

The integral of equation (8) is proportional to the area on the tephigram contained between the environment curve, the 0°C isotherm and the p_d isobar. This area, A_d, is constant for any given snowflake, whatever the environment curve.

When considering a particular snowfall, we are concerned with a large number of snowflakes of different shape, size and physical structure, and the appearance of the precipitation at any pressure level p ($>p_0$) will be determined by A_p, the A-value at that level, since the degree of melting of each individual snowflake will be controlled by A_p. (If $A_p > A_d$, the snowflake will already be completely melted.) The lowest level (p_D) at which the form of precipitation would be reported as sleet will coincide with the level of complete melting of

318

those snowflakes whose A-value is A_D. Hence A_D is constant for any given snowfall, that is

$$\int_{p_0}^{p_D} T_a \, \mathrm{d}(\log p) = \text{const.} \qquad \qquad \ldots (9)$$

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RADIOSONDE TEMPERATURE READINGS AND CLOUD AMOUNT

By D. N. HARRISON, O.B.E., D.Phil.

The work described in this note arose from questions discussed by the Commission for Instruments and Methods of Observation Working Group on the Comparison of Aerological Instruments. The results, though not conclusive, may be of interest as a pointer to further work.

In the first place, it was desired to investigate whether any relationship could be found between the radiation error of radiosonde temperature readings by day and the earth's albedo as measured by the total cloud amount. Such a relationship would be expected on theoretical grounds, for Scrase[1] finds that" a change of 0·1 in the albedo alters the errors by about 7 per cent" and therefore, since the albedo varies from about 0·1 for the earth or sea in the absence of cloud to 0·6 for continuous dense cloud, a variation over a range equal to roughly a third of the radiation correction ought to be shown by the published temperatures, even though these are corrected for radiation, since the corrections applied are independent of the albedo.

To test this, the values of the difference between the temperature at the midday ascent and the mean of the preceding and following midnight ascents at Crawley and Aughton were tabulated for the levels 200, 150, 100 and 70 millibars, together with the total cloud amount at a nearby surface reporting station (Gatwick, 8 kilometres north-north-east of Crawley, and Manchester, 48 kilometres east-south-east of Aughton*). The months January, February, June and July 1960 were taken. The temperatures were taken from the *Daily Aerological Record*; they have been corrected for radiation by the normal method.

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*This is rather a large distance, but it was thought better to use Manchester than Squire's Gate, which is on the coast about 25 kilometres north of Aughton.

TABLE I—DISTRIBUTION OF DAY-NIGHT TEMPERATURE DIFFERENCES FOR JANUARY AND FEBRUARY 1960

Temperature difference °C	70 millibars Cloud amount in oktas (number of occurrences)										100 millibars Cloud amount in oktas (number of occurrences)									
	0	3	4	5	6	7	8	Total			0	1	2	3	4	5	6	7	8	Total
⟩+5								2												0
+5								0												0
+4½								0									1			4
+4					1		2	2									1	2	1	3
+3½					1	2		0										3	3	3
+3						6		1												1
+2½	2					3		0							1		1	1		4
+2								8										3	3	6
+1½								3										3	9	2
+1							1	1										3	7	14
+½					1	1		1									1			13
0							4	4				1					1		6	14
-1								0												9
-1½				3				3				2				3		1	5	8
-2								0										2	3	6
-2½								0										1	3	5
-3								0												1
-3½								0									1			1
-4								0												0
-4½								0												0
-5								0												0
⟨-5								0												0
Mean diff. °C	-0·1	+0·5	-3·0	+1·2	+1·0	+0·5	+0·6	+1·0	+0·6		-0·3	0·0	0·0	+1·5	-0·1	+1·6	+2·6	+0·6	+0·5	
No. of cases	0	4	2	2	4	4	12	24	57		0	7	2	3	5	7	21	43	95	
Standard deviation									2·0										1·8	
Radiation correction (Solar altitude 15°)									-2·8										-2·1	

TABLE I—DISTRIBUTION OF DAY–NIGHT TEMPERATURE DIFFERENCES FOR JANUARY AND FEBRUARY 1960 *continued*

Temperature difference °C	150 millibars Cloud amount in oktas										200 millibars Cloud amount in oktas									
	0	1	2	3	4	5	6	7	8	Total	0	1	2	3	4	5	6	7	8	Total
	number of occurrences										*number of occurrences*									
> +5								1	1	2		1			1	1			3	5
+5									1	1					1	1			1	3
+4½										0		1								1
+4					1		2	1	2	6								2		2
+3½				1		1				2				1				1	1	3
+3				1			2			3		1			1			1	3	4
+2½						1		2	1	4		1	1	1	1			2	4	8
+2						1		1	1	2		1	1	1	1			2	3	7
+1½			1	1			1	3	4	8		1	1	1		2		2	4	11
+1			1	1				3	4	9		1	1					3	2	7
+½	1				1			4	10	10							1	3	6	10
0		2			2		1	2	5	8	2					1		3	2	9
−½		2		1			1	1	1	7	2			1		1	1	3	2	10
−1			1			1		2	3	8	2			1		1	1	1	5	9
−1½		1	1			1			5	7					2	1		2	3	9
−2						1			2	4							2	1		1
−2½									2	2								1	2	5
−3		1							2	3									1	1
−3½		1							1	2									1	1
−4		1							1	4								1		1
−4½					1					0									1	2
−5								1	2	2										0
< −5									2	3							1	1	6	8
Mean diff. °C	—	−1·8	−1·3	+1·8	−0·4	+0·6	+2·0	+0·4	−0·3	0·0	—	+0·8	+1·5	−0·2	+2·6	+1·4	−0·5	+0·3	−0·2	+0·3
No. of cases	0	7	2	3	5	7	7	23	49	103	0	9	3	3	7	9	8	25	53	117
Standard deviation										2·6										3·3
Radiation correction (Solar altitude 15°)										−1·5										−1·2

TABLE II—DISTRIBUTION OF DAY-NIGHT TEMPERATURE DIFFERENCES FOR JUNE AND JULY 1960

Temperature difference °C	70 millibars Cloud amount in oktas (number of occurrences)										100 millibars Cloud amount in oktas (number of occurrences)									
	0	1	2	3	4	5	6	7	8	Total	0	1	2	3	4	5	6	7	8	Total
>+5										1										0
+5										0										0
+4½								1		1						1				1
+4							2	2		4							1	2		3
+3½				2				2	1	4								2		2
+3			2						1	1			1				1	1		1
+2½				2		2	2	4	2	8				1		3	1	6	4	7
+2			2			1	1	4		9			1	1		5	1	4	1	11
+1½				1	1			3	1	8						1	1	4	2	13
+1		1	2		1	3		4	2	9				1		1	1	9		10
+½		2				1	2	2	2	7		1				1	2	7	3	13
0				1		1	2	3	1		3			1		2	2	7	3	19
-½				1					1	8							2	2	2	7
-1			1				3			4						1	1	1	2	5
-1½					1		3		2	5										2
-2			2		1					2										1
-2½						1	1			1							2			2
-3						1				2										0
-3½							1			0										0
-4										0										0
-4½										0								1		0
-5										1							1			0
<-5																				

	0	1	2	3	4	5	6	7	8	Total	0	1	2	3	4	5	6	7	8	Total
Mean diff. °C	—	+0·3	+1·0	+0·3	−1·7	0·0	−0·1	+1·2	+1·1	+0·6	0·0	+0·3	+0·7	+0·5	−0·3	+1·2	−0·1	+1·1	+0·8	+0·8
No. of cases	0	3	4	2	2	13	10	30	13	77	1	4	2	4	2	16	14	39	16	98
Standard deviation										2·0										1·5
Radiation correction (Solar altitude 60°)										−4·4										−3·4

322

TABLE II—DISTRIBUTION OF DAY-NIGHT TEMPERATURE DIFFERENCES FOR JUNE AND JULY 1960 continued

Temperature difference °C	150 millibars Cloud amount in oktas — number of occurrences										200 millibars Cloud amount in oktas — number of occurrences									
	0	1	2	3	4	5	6	7	8	Total	0	2	3	4	5	6	7	8	Total
> +5										0							2	3	6
+5								1		2							3	1	5
+4½			1																—
+4								2		3					1	1	3		5
+4								2		2							3	1	5
+3½								2		3							1		4
+3		2			2	2	2	2	2	4			1	3	1	1	1		10
+2½					2	1	2	3	2	8				3		3	1		7
+2					1		2	5	3	10					1	2	5	1	9
+1½					2	2	3	4	1	9		3		1	1	2	2	1	9
+1		2			4	4	3	9	5	13				2		4	1		6
+½										22									—
0							2	4	5	8		3		2			6		10
−½	1					1		3	5	14							1		8
−1		1		2	2		3	1		7					1		5	1	8
−1½		2						3	1	8				1			2	2	6
−2										3				1					—
−2½						1	2	4	5										9
−3										1							2	1	4
−3½										2					1			1	2
−4										0									—
−4½										0									—
−5										0				1					3
< −5										0									—
Mean diff. °C	0·0	0·0	+3·0	−0·4	+0·2	+0·2	−0·4	+0·8	+1·2	+0·6	+0·7		+0·5	+0·6	0·0	+0·6	+0·8	+0·1	+0·5 +0·6
No. of cases	1	4	2	5	3	17	15	48	24	119	4		4	5	17	15	48	25	120
Standard deviation										1·8									2·9
Radiation correction (Solar altitude 60°)										−2·5									−2·1

323

The results are given in Table I (January and February 1960) and Table II (June and July 1960), in the form of the frequency of occurrence of temperature differences in steps of $\frac{1}{2}°C$, for cloud amounts from 0 to 8 oktas. The mean differences, standard deviations from the mean and approximate radiation corrections are also given. There is a mean difference of about $+\frac{1}{2}°C$ at each level, but no correlation between temperature difference and cloud amount.

Although the cloud amount at a single fixed station is not a satisfactory measure of the albedo as seen by the sonde throughout its flight on all occasions, it seems probable that if a correlation between temperature and albedo existed it would be detected by this method. It is unlikely that the cloud amounts at the radiosonde stations themselves, had they been available, would have given a significantly different result. It can therefore at least be concluded that the total cloud amount does not provide a basis for improving the radiation corrections.

Secondly, for lower levels the question is, what error is introduced by applying the full radiation correction when the sonde is more or less in the shadow of cloud?

The differences between the temperature reading at midday and the mean of the preceding and following midnight soundings were tabulated for the eight stations in the United Kingdom for days in the months May–August 1960 when the neighbouring surface stations reported either (a) a total cloud amount of 0–3 oktas or (b) 6, 7 or 8 oktas of medium or high cloud and 0–4 oktas of low cloud. The results in the form of the mean and standard deviation, for each standard level from 850 to 200 millibars, are given in Table III. The standard radiation corrections for solar altitude 60° have been added for comparison. The stations used, and the relative positions of surface and upper air stations, are listed in Table IV.

TABLE III—MEAN TEMPERATURE DIFFERENCE (DAY–NIGHT) AND STANDARD DEVIATION (°C)

				Pressure level (millibars)					
				850	700	500	400	300	200
						degrees Celsius			
(a)	Mean difference ...	...		−0·3	−0·4	−0·5	−0·7	−0·6	−0·1
	Standard deviation	...		1·2	1·3	1·6	1·7	2·2	2·6
(b)	Mean difference ...	...		−0·5	−0·3	0·0	+0·2	+0·3	−0·2
	Standard deviation	...		1·4	1·4	1·7	1·8	2·0	2·9
Radiation correction for solar altitude 60°	...	...	...	−0·8	−0·9	−1·2	−1·4	−1·6	−2·1

(a) Total cloud amount 0–3 oktas; 130 cases.
(b) Medium and high cloud 6–8 oktas, low cloud 0–4 oktas; 200 cases.

TABLE IV—STATIONS USED

Upper air station	Surface station	Position of surface station with respect to upper air station	
		distance (km)	direction
Lerwick	Lerwick	—	—
Stornoway	Stornoway	—	—
Shanwell	Leuchars	5	S
Aldergrove	Aldergrove	1	W
Aughton	Manchester	48	ESE
Hemsby	Gorleston	11	S
Crawley	Gatwick	8	NNE
Camborne	St. Mawgan	32	NE

Since the greater part of the radiation error is due to direct sunlight, it might be expected that when the sonde is in cloud shadow the application of the radiation correction would result in a temperature reading which is too low by nearly the amount of the correction, and that on the average the final error would be roughly proportional to the amount of cloud above the sonde, at least when the sun is near the zenith. For group (a) the mean cloud amount is about 2 oktas*, so that at 850 millibars a mean error of $-2/8 \times 0 \cdot 8° = -0 \cdot 2°C$ would be expected. For group (b) the mean amount of medium or high cloud is about 7 oktas, so that the expected error at 850 millibars is $-0 \cdot 7°C$. (The presence of some low cloud would tend to make this figure more negative.) The mean day–night differences found are $-0 \cdot 3°C$ and $-0 \cdot 5°C$, but these include the diurnal variation, which presumably tends to be larger on days of low than on days of high cloud amount; if so, the mean differences due to the effect under discussion are more negative than this and the distinction between groups (a) and (b) is obliterated. Thus the results give only qualitative support to the hypothesis, inasmuch as they indicate over-correction for radiation error. At higher levels, as the sonde passes through the cloud, a decrease of the effect would be expected; this is found in group (b), but the positive values here, the increasing negative values in group (a) and the change between 300 and 200 millibars in both cannot be explained in this way. Moreover, the values for 200 millibars in Table III are different from those in Table II. This may be due to sampling errors, as the mean values for 200 millibars are subject to a standard error of about $0 \cdot 25°C$.

As stated above, the temperature readings were taken from the *Daily Aerological Record*. A number of very large day–night differences occur, some of which at first sight suggest errors in the published figures. These have been examined as far as possible, and in many cases an outstandingly large value at one station is confirmed by a similar one at another; the general impression created is one of confidence in the data. No alterations were made, and no reading was excluded from the analysis merely because it looked improbable.

I am indebted to Mr. R. Brown for the computations on which this note is based.

REFERENCE

1. SCRASE, F. J.; Radiation and lag errors of the Meteorological Office radiosonde and the diurnal variation of upper-air temperature. *Quart. J. R. met. Soc., London*, 80, 1954, p. 565.

REVIEWS

Handbuch der Aerologie, edited by W. Hesse. 9 in. × 6½ in., pp. 897, *illus.*, Akademische Verlagsgesellschaft Geest & Portig K.-G., Leipzig, 1961. Price: 80 *DM*.

The author of the term "aerology" was W. Köppen who proposed it in 1906 at a meeting of the International Commission for Scientific Aeronautics in the following words: "The name aerology is recommended for the new branch of meteorology which has the study of the free atmosphere as its task and balloons and kites as its instruments". The term found ready acceptance as is shown by its use in a report presented to the International Meteorological Committee in 1907.

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* It is noticeable that cloud amounts 1 and 3 oktas are much more frequent than 0 and 2.

In the years which have elapsed since Köppen made his proposal the scope of the study covered by the term has, on paper at least, increased as much as the apparatus at its disposal if we accept the present definition to be that printed in the opening lines of the book under review. They run: "Aerology, a subdivision of meteorology, is the science which conducts research into the physical and chemical states and processes in the atmosphere". The terms of reference of the World Meteorological Organization Commission for Aerology state that the Commission is responsible for questions relating to research in the physics and dynamics of the atmosphere, the scientific evaluation of technical meteorological procedure, the standardization and tabulation of physical functions and constants and the standardization of nomenclatures and classifications in physical and dynamical meteorology.

This Handbook might well be expected, on the basis of the recent definitions, to be a comprehensive textbook of physical and dynamical meteorology. In fact its scope is broadly that stated in Köppen's original definition.

The Handbook is divided into six parts entitled respectively Historical Development, Thermodynamics, Classical (i.e. roughly Köppen's) Methods of Measurement, New Methods of Measurement, Aerological Measurements, Applications of Aerological Measurements. The titles of the last two parts do not clearly describe their contents. In his preface the editor, W. Hesse, writes that he has striven to attain completeness especially in instrumental matters. Only in the chapters on the synoptic and climatological uses of aerological observation does he admit to having imposed space restrictions.

The first part written by W. Hesse himself is a most interesting outline of the development of instruments for observing in the upper air, from the flight of the first free balloon to be equipped with a barometer and thermometer to the rocketry of today, followed by a summary of arrangements for international co-operation in aerological work.

The second part, by Professor F. Möller and Dr. K. Bullrich, is a thorough account of atmospheric statics and thermodynamics, standard atmospheres, the representation of the state of the atmosphere on thermodynamic diagrams and the use of these diagrams in determining the degree of stability and height of condensation level. All types of aerological diagram are described with a natural emphasis on the Stüve diagram. Blank copies of the actual thermodynamic diagrams used in the weather services of the German Federal Republic and the German Democratic Republic are contained in a pocket in the back cover.

The third part consists of two chapters, the first by Dr. P. Dubois of Lindenberg Observatory on the technique of kite and tethered balloon ascents over land and the second by Dr. E. Huss of Friedrichshafen on similar ascents from water. The chapter on the land ascents is written in great detail with large figures of the construction of such fittings as cable coupling links and, apart from its historical interest, it should be of practical value in this still widely used method of obtaining instrumental recordings in the lowest kilometre. Particular interest in this chapter attaches to the methods developed at Lindenberg in 1937 to 1939 for holding a kite-balloon at a relatively "fixed point". These methods, no account of which has so far as the reviewer could ascertain previously been published, enabled a meteorograph to be held at a height of 530 metres with oscillations of only three metres. Interesting thermographs in stable and unstable air masses from such a meteorograph are reproduced. Huss

in the second chapter describes the methods employed in the well known ascents from Lake Constance directed for many years by W. Peppler.

The fourth part which is on newer methods of measurements contains five chapters respectively on the use of gliders by Professor W. Georgii, the use of powered aeroplanes by the late Professor H. Berg, radiosondes by Dr. J. Rink, the measurement of ozone by Dr. H. K. Paetzold and on rockets by Professor E. G. Schwidkowski (or in the international transliteration system E. G. Švidkovskij). The two writers on gliders and aeroplanes naturally deplore the tendency to abandon regular ascents by aircraft as the radiosonde network has been enlarged. Georgii's article describes the uses of gliders for observing several elements, notably atmospheric electricity, in which connexion the absence of electrification from exhaust gases gives gliders marked advantages. Georgii also describes in detail the observation of the air currents of orographic waves by both gliders and aeroplanes. The late Dr. Berg's chapter is very comprehensive on observations from aeroplanes ranging from the selection of the staff to practical details of instrumentation and hints on visual observations. Berg was in charge of German meteorological reconnaissance units during the Second World War and writes from an obviously deep experience of his subject. Rink's chapter on radiosondes is also very comprehensive. It opens with a history of the development of the radiosonde by Bureau and Idrac, Duckert, and Molčanov in the late 1920s and goes on to the general principles of operation with details of several types which appear to include all those now in use. Calibration and correction of errors, that for radiation relying largely on the work of Scrase, are well covered. Besides the conventional ones radiosondes for the detection of the presence of cloud, measurement of radiation and of cosmic radiation, and the electric potential gradient are described. The author is well aware of the deficiencies of the radiosondes now in use but does not give an example, such as can be found in the literature, on the "discontinuities" in upper air charts associated with different types of radiosonde. These "discontinuities" are briefly mentioned by Reuter in his chapter on synoptic aerology as being very disturbing at 300 millibars and above, but again no actual instance is given. Rink has a poor opinion of making comparisons between different types of radiosonde by suspending a number from one balloon and considers the only satisfactory way will be found to be comparison against a specially made standard test sonde which would use only electrical sensitive elements such as thermistors.

Paetzold's chapter on ozone is a small-scale treatise on the whole subject with emphasis, in conformity with the general trend of the Handbook, on methods of observation. The chapter on rocketry by the Russian Professor Schwidkowski is a broad summary without great detail of the measurement of meteorological elements in the high atmosphere from rockets and of the determination of air density from changes in satellite orbits. Both American and Soviet work are described. The possibility of the television of cloud systems from satellites is mentioned, but no statement that cloud photographs from a rocket or satellite have in fact been taken is made, though the article must have been written after the publication in the *Monthly Weather Review*. June 1955, of the cloud system of a Caribbean hurricane.

The fifth part consists of three chapters, one on methods of measuring upper winds by Professor Dr. H. G. Müller, one on turbulence and aircraft bumpiness by Professor H. Lettau and the third on the aerology of atmospheric electricity

by Professor H. Israël. Müller's chapter is comprehensive, ranging from the nephoscope through pilot balloons to the various radar methods in detail. As an example of the degree of detail there is a sectional drawing of an automatic valve for filling pilot balloons. The only thing the reviewer missed was an account of the magnitude of errors in wind-finding by the various methods, a matter on which several papers including some in German have been published. Lettau gives an excellent account of the meteorology of aircraft bumpiness based largely on recent American work such as the Jet Stream Project and the British work of Jones, Bannon, Chambers and Turner. Israël's chapter describes methods of making measurements of potential gradient, current, and conductivity in the free air and provides an outline of the results of observation which is particularly strong on the relation between meteorological and electrical turbulence.

The sixth part contains two chapters, the first on synoptic aerology by Professor H. Reuter and the second on aerological climatology by Professor H. Flohn. The synoptic aerology chapter is a survey of the computation, dynamics and forecasting of upper air flow patterns. The thermodynamic diagram aspect of synoptic aerology was covered in Part 2. Reuter opens with the construction of contour thickness and isotach charts, and the computation from them of wind and thermal wind with corresponding theory. There follows the construction and use of charts of isopleths of humidity mixing ratio on an isobaric surface. Next we have the representation of flow in zonal sections, the properties of jet streams, the mean variation of wind with height, the major flow patterns such as long waves and blocking highs. Finally there is the forecasting of upper flow starting with Petterssen's kinematic extrapolation method and going on to numerical prediction based on the vorticity equation by graphical and machine methods, and concluding with the regression methods due to Namias and Reuter himself. Reuter considers the regression methods a valuable and indeed at present necessary support to the dynamical ones. One misses in this otherwise wide cover any mention of the direct forecasting of upper winds by the regression equations deduced by Durst and his collaborators. Flohn's chapter on aerological climatology opens with sections on the practical handling for climatological purposes of the individual elements followed by critical summaries, arranged geographically, of the literature of upper air climatology. Finally there are sections on the climatology of special features such as inversions in the lower layers, the tropopause, and layers of maximum wind, in which there are steep gradients of the elements concerned, and on the computation of large-scale transport processes in the general circulation such as water vapour transport in monsoon regions and meridional transport.

The book ends with a collection of tables of means, frequencies, standard deviations and extremes of temperature, humidity and wind in the free air. The tropospheric temperature table is for 195 stations including Arctic ice-islands, ocean weather ships and the Antarctic International Geophysical Year stations some of which give observations for only a year. The other tables are for much fewer stations, the one giving the frequency distribution of relative humidity being only for Erlangen, Larkhill, Habbaniya, Aden and Stanley. Each chapter is followed by a bibliography. Those on radiosondes and aerological climatology, each of which has over 200 references, and those on the 19th century literature following the historical chapters will be found particularly useful. The book is on the whole very up to date, a reference even being made by Flohn

to *Geophysical Memoirs* No. 102 by Bannon and Steele on the average water vapour content of the air, published as recently as May 1960.

The text and bibliographies are in general very accurate and the few mis-spellings should not lead to confusion. The date of Seville Chapman's paper on thundercloud electrification in the bibliography on p. 697 should be 1953 not 1931. The figures are clear and photographs well reproduced. The only error noted was in Figure 23 illustrating the various types of stability and instability in which the two diagrams for latent and pseudo instability are incorrectly shaded.

What is the overall value of this immense work? The preface gives the reason for publishing it in the following words: "German meteorologists have played a great part in meteorological research, in the development of methods of aerological measurement, in the founding of aerological observatories and the establishment of aerological networks. No corresponding book exists in the German language. Therefore the editor and publisher hope that the book will fill a gap in meteorological literature". The work is hardly a handbook of tables and figures for reference and computing as, though it contains a number of such tables and figures, they are scattered and not brought together in the numbers or convenient manner of Linkes Taschenbuch or Smithsonian Tables.

Clearly this book should be in the library of every national meteorological service or university department of meteorology. The historical material forms a unique collection and the chapters on methods of observation from aircraft, on the use of kite-balloons, on radiosondes and on the climatological handling of upper air observations will be of much value to the specialists in these subjects. In the reviewer's opinion it would have been better to have firmly omitted all the material to be found in general textbooks, in particular the thermodynamics, in order to keep the price at a level which individual meteorologists concerned with upper air observations can afford.

The style of the German is direct and easily readable, the printing clear and the binding good.

<div style="text-align: right">G. A. BULL</div>

General climatology, by Howard J. Critchfield. 9½ in. × 6 in., pp. xiii + 465, *illus.*, Prentice-Hall International Inc., London Branch, 34–36 Beech Street, London, E.C.1, 1960. Price: 50s.

It is always interesting to read the preface of a book in order to compare what the author says he has set out to do with what he has actually done in the contents. This is particularly revealing with regard to the class of reader and the level of knowledge at which the book is aimed. *General climatology* appears to be aimed at almost all conceivable types of potential reader: "businessmen, sportsmen, students of geography, earth sciences, biology and social studies". Although mathematics and physics are declared unnecessary for understanding the fundamentals of general climatology "the reader is urged to consult current journals for reports on the latest sensational breakthrough"! The text that follows is divided into three sections, one dealing with each of physical, regional and applied climatology.

At the outset one is astounded to read that climatology, although closely linked with meteorology, is a branch of geography. But soon after this come the

best three pages in the book which take the form of a short but excellent essay on the history of meteorology and climatology. The remainder of Part I deals with physical climatology and is reasonably comprehensive; but so many branches of atmospheric physics are treated as within the realm of physical climatology (including weather forecasting) that one wonders what is left for meteorology. Part of the section dealing with pressure and winds is most misleading; we are told, for example, that "it is the slight differences in pressure which motivate winds that transfer moisture and temperature quantities from one area to another" and "a pressure gradient is the immediate cause of all air movement; the direction of flow is from high pressure to low pressure". Herein lies the key to many geographers' misunderstanding of the dynamics of the atmosphere. The concept of motion under a *balance* of forces, and that only under very special circumstances does air flow directly from high to low pressure should have been made clear. This confusion extends to the "winds aloft" section where the treatment is muddled and at times incorrect. In the "extra-tropical cyclone" section it is amazing to find that a modern textbook, for whatever section of reader, can treat the frontal development sequence without a single reference to the upper wind pattern and the possible existence of a jet stream.

Part II deals with climatic classification, and here the author is obviously on more familiar ground; but the treatment has no particular merit and is merely a rehash punctuated with arid statistics, with little reference to the dynamics of climate, and no reference to modern ideas on dynamical climatology that have been developed over the past ten years.

The final part gives a comprehensive survey of the various fields of applied climatology, and here the treatment can be recommended to the non-specialist. However, it is a pity that the interesting climatological problems associated with the design and construction of dams are not mentioned; also, the urgency of the flood forecasting problem in hydrology could have been emphasized by including a typical hydrograph showing some examples of the rapid rise and fall of river levels.

Finally, therefore, the section on applied climatology is well done, but the book cannot be generally recommended because it contains some of the worst aspects of the geographers' approach to climatology.

G. B. TUCKER

Physical oceanography, by Albert Defant. Two volumes, 10 in. × 7 in., Vol. I, xvi + 729, *illus.*; Vol. II, viii + 598, *illus.*; Pergamon Press Ltd., Headington Hill Hall Oxford, 1961. Price: £10 10s.

These volumes form an excellent up-to-date textbook on physical oceanography. Their publication was expensive and was made possible by a grant from the United States Office of Naval Research.

Although Professor Defant has spent much of his time on oceanographical research he is also noted for his work in the field of meteorology and on the interaction between the atmosphere and ocean. His name will be associated among others in the mind of some readers in this country with the "Meteor" expeditions, but many meteorologists will also be familiar with other aspects of his work.

The first part of Volume I describes the ocean and its physical and chemical properties and their distribution: it also includes a chapter on evaporation

from the sea surface and the water budget of the earth, and a chapter on sea ice. Dynamical oceanography is the subject of Part II of this volume: in reading it one is reminded time and again of the many similarities of the theories of the ocean and the atmosphere. The subject of Volume II is waves, tides and their related phenomena.

Many people will find Chapter I, Volume I, entitled "The Ocean" to be of general interest. The meteorologist will find in addition much of interest in the chapters on temperature, evaporation and the water budget and sea ice, as he will in much of Part II on dynamical oceanography. The marine meteorologist will find the sections of Volume II on waves applicable to his work, although they deal with this subject in great detail. Otherwise this volume will be chiefly of interest to oceanographers and tidal experts.

A few of the statements in the book may be open to criticism: for example, in Volume II, page 43, Defant states that in the North Atlantic the extreme wave heights are from 12–13 metres, and in exceptional circumstances higher waves occur through interference. In fact at ocean weather station I in the years 1949–53 over 0·1 per cent of all wave heights observed were over 43 feet, a percentage which is perhaps greater than that suggested by the word exceptional. That criticism of such finer points is possible may often be due to the fact that this work was translated from German into English before publication.

These volumes are naturally not intended primarily for meteorologists, few of whom will read the publication in full. It will probably for them, however, replace *The Oceans* by Sverdrup, Johnson and Fleming as a standard reference on physical oceanography.

Pergamon Press are to be congratulated on the first class production of these volumes which will provide a vast source of information for the oceanographer.

P. R. BROWN

CORRIGENDUM
Airflow over broad mountain ranges
In equation (2) on page 222 of the August 1961 *Meteorological Magazine*, for l read e.

METEOROLOGICAL OFFICE NEWS
Retirement.—The Director-General records his appreciation of the services of:

Mr. G. Bell, Senior Scientific Assistant, who retired on 24 September 1961. He joined the Office in June 1934 as an Observer, Grade II, having previously served in the Royal Air Force from 1920 to 1932. The greater part of his service has been spent at aviation outstations, with periods at Headquarters from 1942 to 1945 and from 1947 to 1949. At the time of his retirement he was serving at the Manchester Weather Centre. Mr. Bell has accepted a temporary appointment in the Meteorological Office.

Sports activities.—The 33rd Air Ministry Annual Sports Meeting was held at the White City Stadium on 13 September 1961. The Meteorological Office retained the W. S. Jones Cup for the Division scoring the highest number of points at the Annual Sports. We also won the Ladies' Relay Cup and the Men's Relay Cup. Mr. C. W. Fairbrother won the High Jump Cup and Miss V. J. Lewis the Victrix Ludorum Cup, the 100 yards Cup, the High Jump Cup and the Long Jump Cup.

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DR162